Data Mining M
Machine Learning and Data Mining
Introduction

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Context

- Exam **Data Mining M**
  Master program Computer Engineering, second year
- Module **Machine Learning and Data Mining**
  part of Machine Learning and Deep Learning (i.c.)
  Master program Artificial Intelligence, first year
- Official course site
  - https://www.unibo.it/en/teaching/course-unit-catalogue/course-unit/2023/468022
- E-learning site on **`https://virtuale.unibo.it`**
  - can be reached following the link from the official course site
  - students having the course in their study plan can self-enrol

What's in this Course

- **Part 1 – Data Mining**
  We will focus on the data side, studying the enabling technologies which have been developed for other purposes, but can positively influence the success of data mining processes
  - Data Warehouse
  - Data Lake
  - Software Architectures for Data Mining processes
- **Part 2 – Machine Learning**
  We will focus on the techniques that support data–driven decisions
  - Data preparation
  - Classification
  - Regression
  - Clustering
  - Association rules

Insight

Education is not the piling on of learning, information, data, facts, abilities or skills – that's training or instruction – but is rather making visible what is hidden as a seed

Thomas More[1]

1 Cited by Charu C. Aggarwal in his book "Data Mining – the Textbook"

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Data, Data Mining and Machine Learning

- Data exists independently from Data Mining and Machine Learning
  - but you need Data Mining and Machine Learning techniques to derive interesting and actionable insights
- Data Mining and Machine Learning were created long before the dramatic increase of the amount of data available
  - the increase of the amount of data strengthen DM and ML relevance and economic impact

Big Data

A new player with Data Mining and Machine Learning

- Big Data exists independently from Data Mining and Machine Learning
  - but you need Data Mining and Machine Learning techniques to effectively analyse and use Big Data
- Data Mining and Machine Learning were created long before the existence of Big Data
  - but using them on Big Data greatly increase DM and ML relevance and economic impact

Data → Information → Knowledge ⇒ better, data driven, decisions

Data: a collection of raw value elements

Information: the result of collecting and organising data

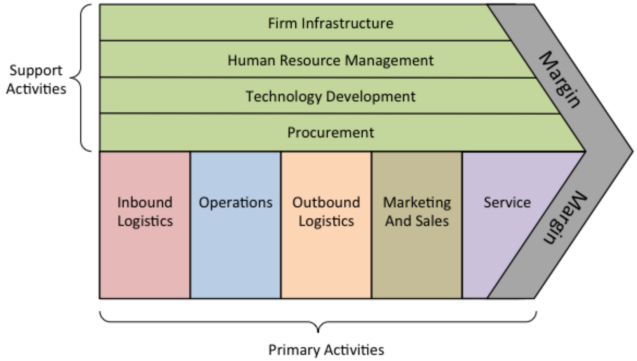
- ⇒ relationships between data items
- ⇒ context
- ⇒ meaning

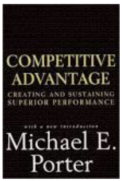
Knowledge: understanding information based on recognising patterns

Increasing insights

Where does *data* come from? 1/2

A *business process* is a set of activities that, once completed, will achieve an *organisational goal* (e.g. deliver your product to your customer)





https://en.wikipedia.org/wiki/Value_chain

Where does *data* come from? 2/2

- When an event in the real world *changes the state* of the enterprise, one of the events below happens
  - a *transaction* is executed to reflect the corresponding change in the *database*
  - a signal is collected from the infrastructure and stored somewhere
- A *transaction* is a business event that generates or modifies data stored in an information system (database)
- A *signal* is the reading of a measure produced by a sensor
- Data may also be provided by *external subjects*

OLTP (On-Line Transaction Processing)

- a class of software programs capable of supporting transaction-oriented applications and data storage
- designed to record the daily routine transactions necessary to run the business
- key goals: availability, speed, concurrency and recoverability

ERP (Enterprise Resource Planning)

An *integrated system*

- can manage all the business processes of all departments within a single software product
- a common database supports all the applications
- operates in or near real time
- has a consistent look and feel across modules
- e.g. SAP

https://en.wikipedia.org/wiki/Enterprise_resource_planning

MIS (Management Information Systems)

- standardized and fixed reporting systems built on existing OLTP
- support structured, operational decision making
  - decisions that can be described in detail before the decision is made
- used by both managers and employees
  - generate performance indicators

DSS (Decision Support Systems)

- interactive and user-friendly analytical system
- provides support for complex and unstructured decisions
  - decisions that cannot be described in detail before the decision is made
- attempt to combine the use of models or analytic techniques with traditional data access and retrieval functions

EIS (Executive Information Systems)

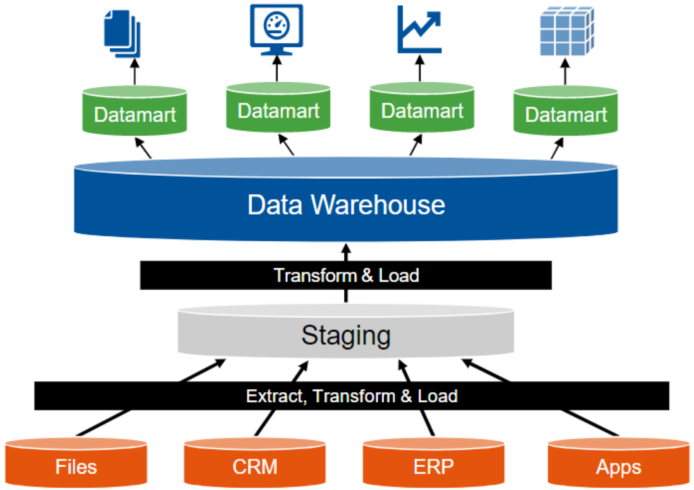
- support the executive level of management
- are used to formulate high level strategic decisions impacting the direction of the organisation
- usually have user friendly interfaces and the ability to extract summary data from internal and external systems

BI (Business Intelligence)

Several definitions

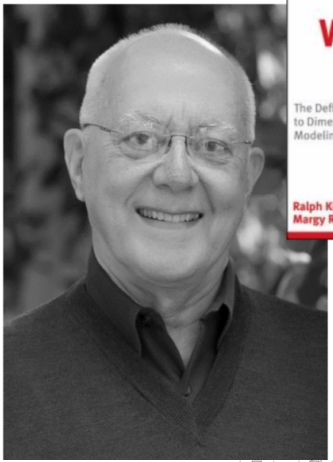
- "applications, infrastructure, tools and best practices that enable access to and analysis of information to improve and optimise decisions and performance" (Gartner)
- "a set of methodologies, processes, architectures, and technologies that transform raw data into meaningful and useful information used to enable more effective strategic, tactical, and operational insights and decision- making" (Forrester Research)

BI Architecture



Data Warehouse

Ralph Kimball (1996)
"Data Warehouse is a copy of transaction data specifically structured for query and analysis"



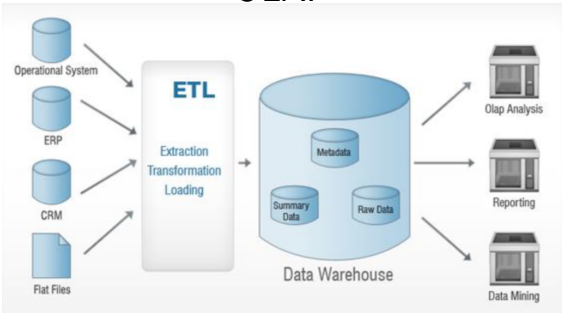
OLAP (OnLine Analytical Processing)

- Analyse multidimensional data interactively from multiple perspectives
- Roughly speaking: extensive usage of group by and summary functions with easy selections, projections, column exchanges, ...
- Uses algorithms and data structures specifically designed to ease these operations
  - e.g. *data cube*
- Some typical OLAP applications: business reporting for sales, marketing, management reporting, business process management (BPM), budgeting and forecasting, financial reporting

MIS vs OLAP

Management Systems
OLTP

Analytical Systems
OLAP



Structured vs unstructured decisions

Structured		*Unstructured*	
Description	***Example***	***Description***	***Example***
Made under an established situation	Hiring a new employee	Made under an emergent situation	Fire breakout
Programmed	Start the monthly payment of salaries	Unplanned	Opportunity for financial investment
Fully understood	When a bank customer makes huge fund movements ask him the reason	Unclear or uncertain	Necessary to acquire information to understand which operation is to be performed
Routine task	Hiring new personnel in a given sector	Suddeen 0ne-shot situation	Dealing with a labor strike
Specified process	Manufacturing something	General processes	Managing security for IT equipment
Well defined methodology	Possible withdraw of funds from international accounts according to currency rates	Decisions relying on knowledge and/or expertise and on analysis of information	What new market segment could be targeted

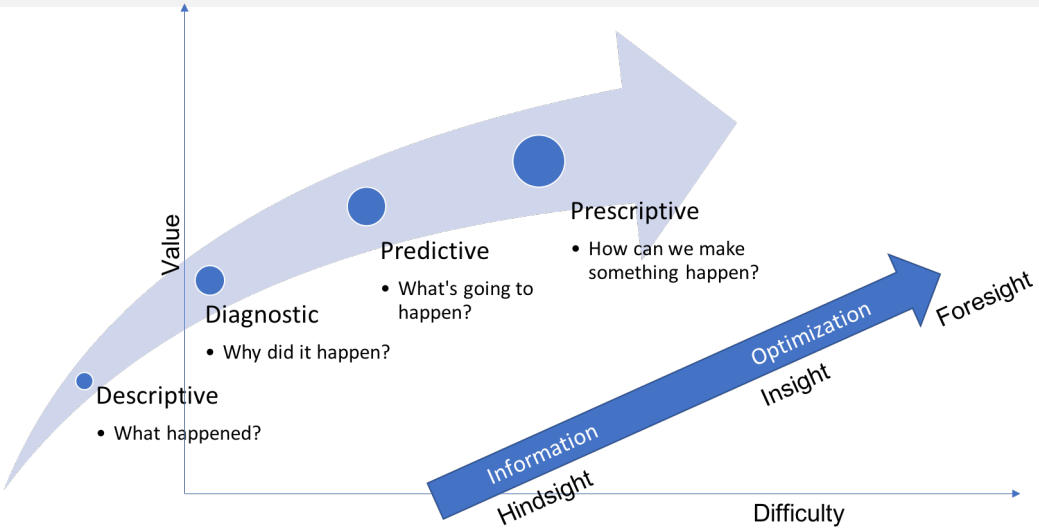
Analytics vs Data Mining

Analytics – Structured decisions driven by data

Data Mining – Unstructured decisions driven by data

Sometimes they can provide insights in order to define a new structured decision

Analytics


Value
Descriptive
• What happened?
Diagnostic
• Why did it happen?
Predictive
• What's going to happen?
Prescriptive
• How can we make something happen?
Information
Insight
Foresight
Optimization
Hindsight
Difficulty

Analytics

- descriptive
  - aggregate data with DB techniques, understand data, descriptive statistics and unsupervised machine learning
- diagnostic
  - descriptive + domain knowledge, understand causes
- predictive
  - calculate the most probable value of a variable in a future time, given the history of a set (sequence) of variables
- prescriptive
  - suggest actions to be taken to obtain the desired effect, choose among options and strategies, optimize

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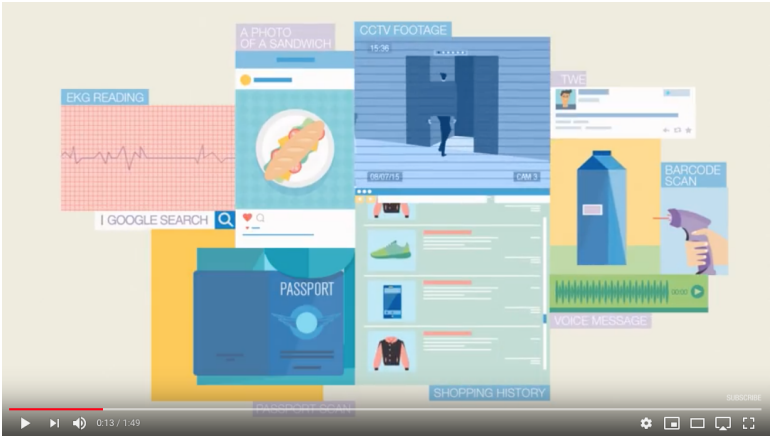
Paradigm Shift

- It is not easy to manage and transform raw data from OLTP/ERP systems into information
- over time (from 1960's to today) the market found solutions
  - databases, SQL, Data Warehousing, OLAP, etc.
- now the world of data is facing a *paradigm shift*

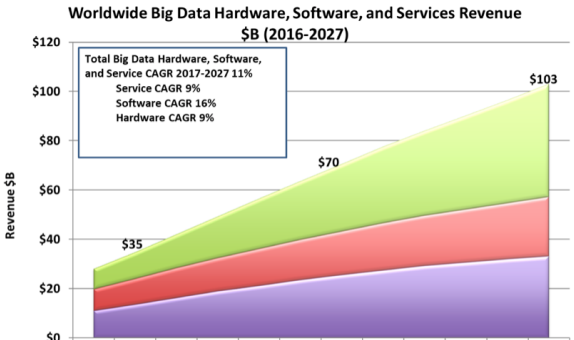
Look at this



https://www.youtube.com/watch?v=eVSfJhssXUA

Why are we talking about that?

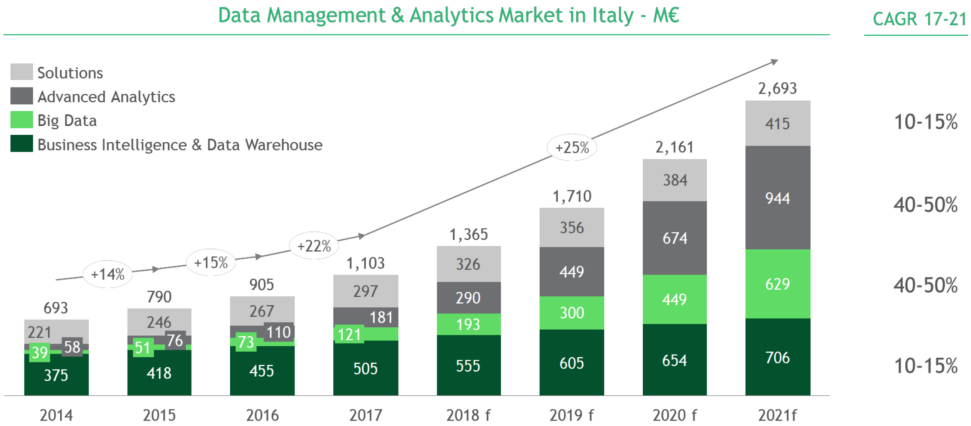
- Worldwide IT spending is projected to total $3.7 trillion in 2018, an increase of 4.5 percent from 2017, according to the latest forecast by Gartner
- Big Data has a significant share



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Software	$8	$11	$14	$17	$20	$24	$27	$31	$34	$38	$42	$46
Hardware	$9	$10	$12	$14	$15	$16	$18	$19	$20	$22	$23	$24
Service	$11	$14	$16	$19	$21	$24	$26	$27	$29	$31	$32	$33
Total Big Data	$28	$35	$42	$49	$56	$64	$70	$77	$84	$90	$96	$103

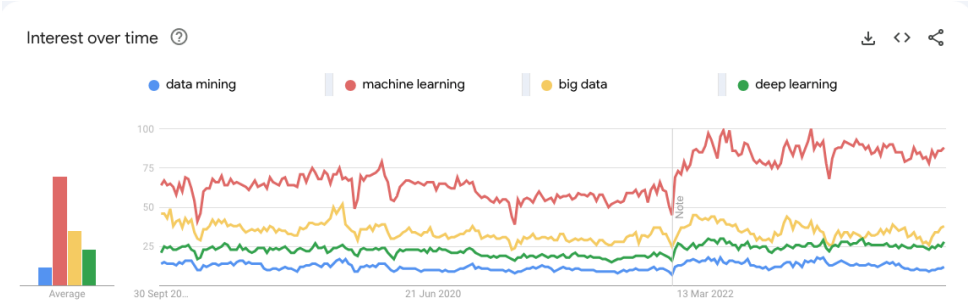
Source: wikibon.com

Spending in *data* has constant and continuous growth

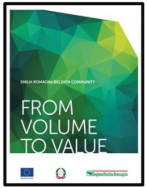


Why are we talking about that?

Google Trends - Last 5 years



Why are we talking about that?



"70% of the super-calculation capacity in Italy is concentrated in Emilia-Romagna. On big data alone we have a network of 1,800 engineers, 230 foreign researchers on a permanent basis and 60 higher education courses. The future of manufacturing, sciences, medicine is based on the ability to manage huge amounts of data. We don't have to invent anything. We already have everything, it just needs to be put into the system"

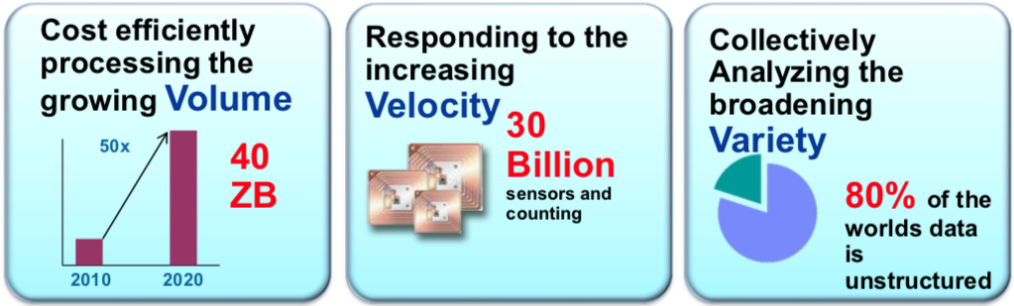
Patrizio Bianchi (former Councilor Emilia–Romagna Region)

Data Revolution

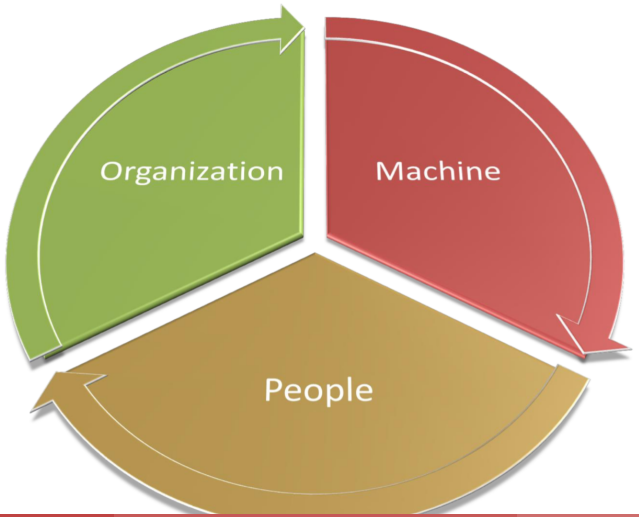
- Flood of Data from new sources
  - Social Networks, Internet of Things (sensors), smartphones, wearable devices, Industry 4.0, GPS, Smart Cities, Home automation, ...
- ... more data has been created in the past two years than in the entire previous history of the human race!

Let's get to the point

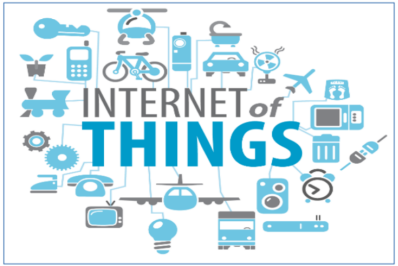
- Organisations struggled to collect data to improve the *decision process*
- Now they have *a lot of data*, *Big Data*
- It is not easy to extract value from such a Big Data

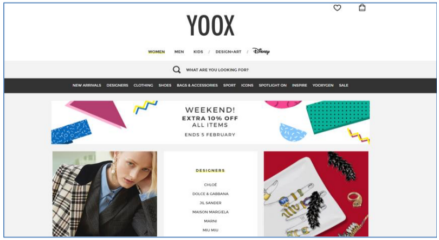


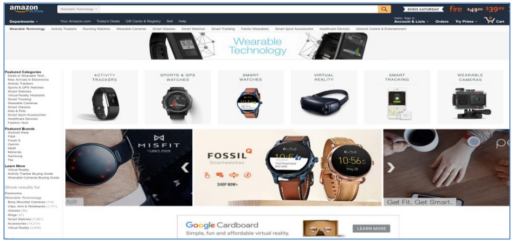
Data Sources

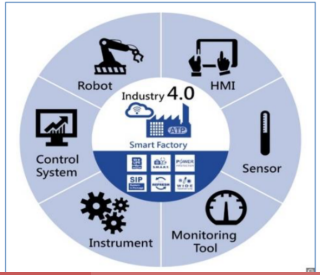


Machine–Generated Data









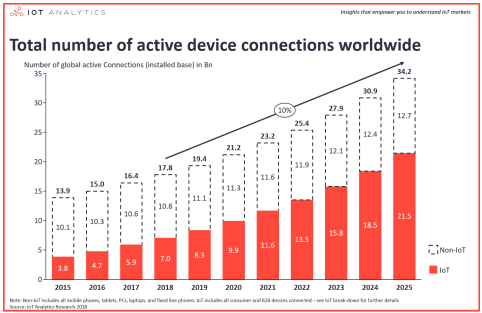
IoT (Internet of Things)

Phenomenal growth in the number of sensors and machines used to measure and record the events and situations in the physical world

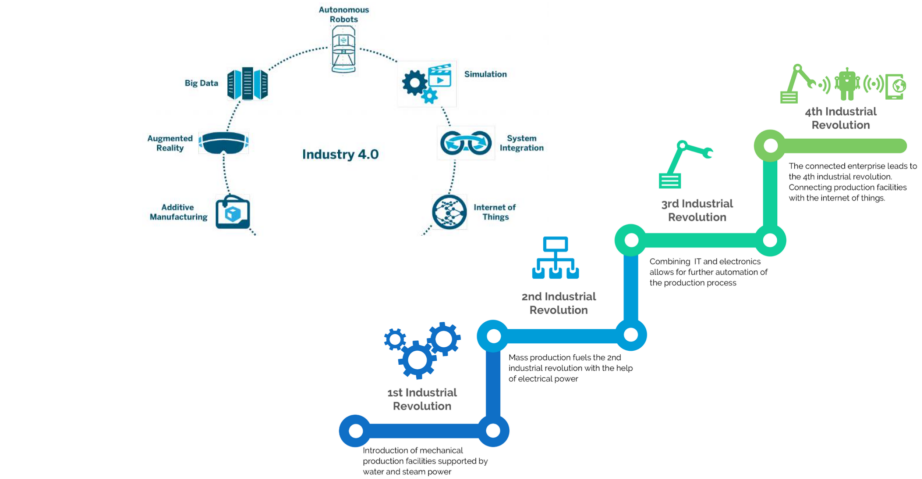
- Well-structured data, suitable for computer processing
- Size and speed beyond traditional approaches
- Data from sensors:
  - Fixed sensors
    - Traffic sensors/webcam, Home automation, Weather/pollution sensors, Scientific sensors, Security/surveillance videos/images, ...
  - Mobile sensors (tracking)
    - Mobile phone location, Cars, Satellite images, ...
  - Data from computer systems
    - Logs, Web logs, ...

IoT – Sensors

- More than 20 billion objects in 2020 are interconnected and connected to the Internet
- They will be always connected, pervasively installed in environment, mixed with people and machines
- Are all the valuable assets well managed?



Industry 4.0


Autonomous Robots
Big Data
Simulation
Augmented Reality
Industry 4.0
System Integration
Additive Manufacturing
Internet of Things
1st Industrial Revolution
Introduction of mechanical production facilities supported by water and steam power
2nd Industrial Revolution
Mass production fuels the 2nd industrial revolution with the help of electrical power
3rd Industrial Revolution
Combining IT and electronics allows for further automation of the production process
4th Industrial Revolution
The connected enterprise leads to the 4th industrial revolution. Connecting production facilities with the internet of things.

Industry 4.0

Economic growth has been slowing for the past 50 years, but relief might come from an unexpected place — a new form of manufacturing that is neither what you thought it was nor where you thought it was. Industrial systems thinker Olivier Scalabre details how a fourth manufacturing revolution will produce a macroeconomic shift and boost employment, productivity and growth.

https://www.ted.com/talks/olivier_scalabre_the_next_manufacturing_revolution_is_here?language=en

People–Generated Data

Company	Data Processed Daily
eBay	100 Petabytes (PB)
Google	100 PB
Facebook	30+ PB
Twitter	100 Terabytes(=.1PB)
Spotify	64 Terabytes

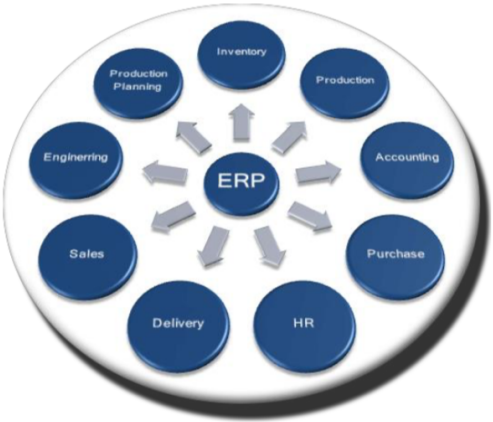
- Social media: Facebook, LinkedIn, Instagram, Youtube, . . .
  - daily, huge amounts of new data
- Text–heavvy, unstructured, no well-defined data model

In 60 seconds . . .

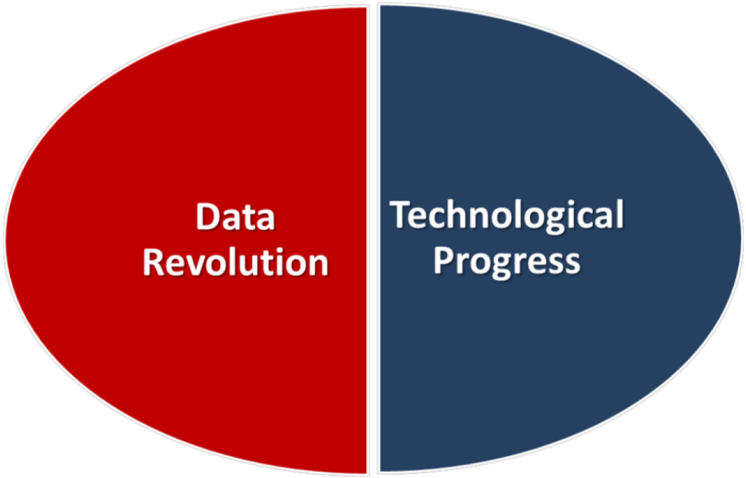
Organisation–Generated Data

Common types of organisational big data:

- commercial transactions, credit cards, government institutions, e-commerce, banking or stock records, medical records, sensors, transactions, clicks, ...



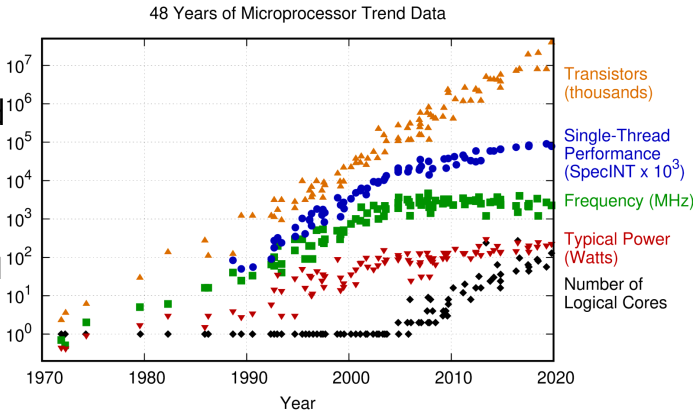
Key Enablers



Technological Progress

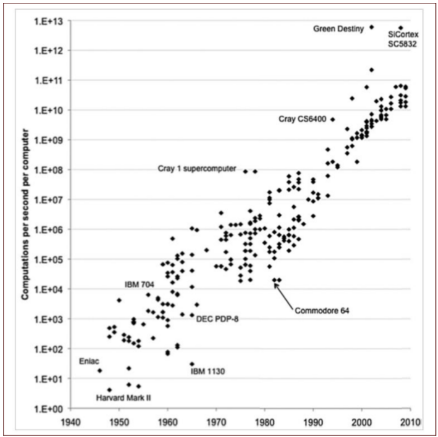
Technological Progress

- The number of transistors on integrated circuits doubles approximately every 2 years?
  - Gordon E. Moore, Intel co-founder, 1965



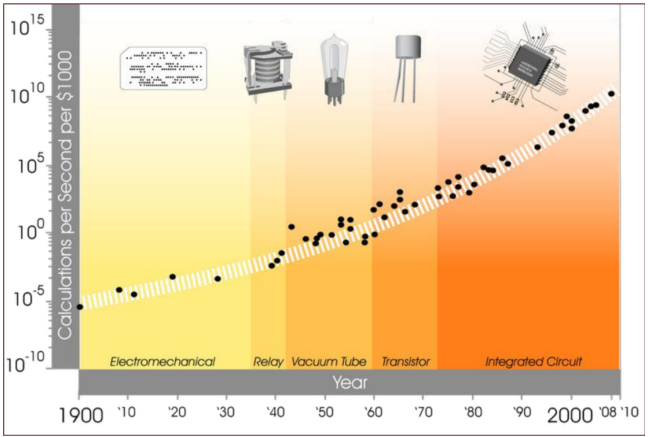
Computational Capacity

- Computational capacity increases also thanks to architectural advances



Calculations per second per $1000

- Dramatic drop in the cost of computation
  - figure produced by Ray Kurzweil



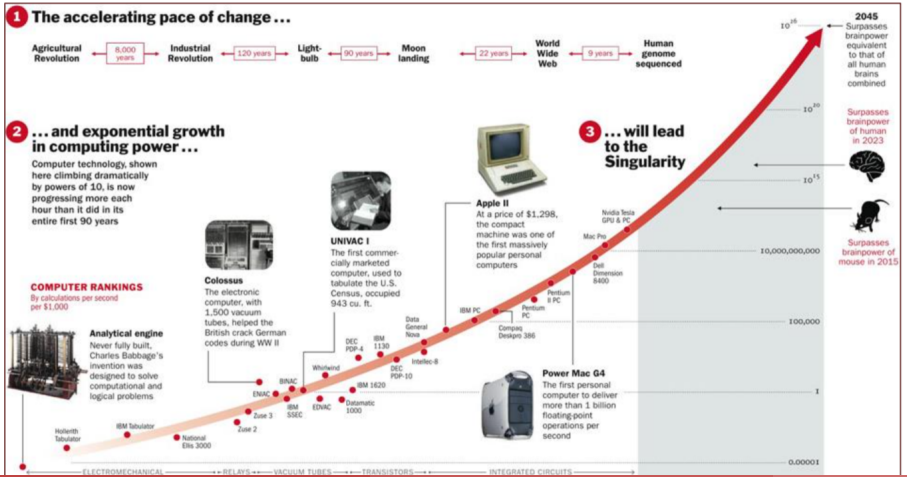
Exponential Increase in Storage Capacity

. . . and Decrease in Storage Costs

- Changes in storage capacity and costs where subject to big leaps, rather than to linear laws
- In the last 40 years they have been even bigger than the changes in computational capacity

The IBM Model 350 disk file with a storage space of 5MB from 1956 and a Micro SD Card

Technology keeps progressing



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Cloud Computing

- Is a *delivery model*
- Access to a shared pool of configurable computing resources
  - servers, storage, databases, software, networks, ...
- On–demand
- Pay–per–Use
- Like a *utility*, e.g. electricity
- Fast provisioning and deploying

Cloud Offerings by Service

More Structured

↓

Less Structured

Software as a Service (SaaS)

Facebook, Salesforce.com, Gmail

Platform as a Service (PaaS)

Google App Engine, Microsoft Azure

Infrastructure as a Service (IaaA)

3Tier, Amazon EC2, Rackspace, GoGrid

Less Control

↑

More Control

Cloud Offerings by Service

SaaS (Software as Service): Consumer uses provider's applications running on provider's cloud infrastructure

PaaS (Platform as Service): Consumer can create custom applications using programming tools supported by the provider and deploy them onto the provider's cloud infrastructure

IaaS (Infrastructure as a Service): Consumer can use computing resources within provider's infrastructure upon which they can deploy and run arbitrary software, including OS and applications.

Cloud – Benefits I

Scalability: resource is available as and when the client needs it and, therefore, there are no delays in expanding capacity or the wastage of unused capacity

No investment in hardware: everything is set up and maintained by the cloud provider, saving the time and cost of doing so on the client side

Pay for what you use: if the service is only needed for a limited period then it is only paid for over that period and subscriptions can usually be halted at any time

Cloud – Benefits II

Updates are automated: Updates will usually be free of charge and deployed automatically by the cloud provider

Disaster Recovery and Security: managed by the provider

Flexibility and Scalability: can easily increase on demand the amount of computational power/storage space

Accessibility: work from anywhere with web browser and pc/mobile device

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From data to Big Data

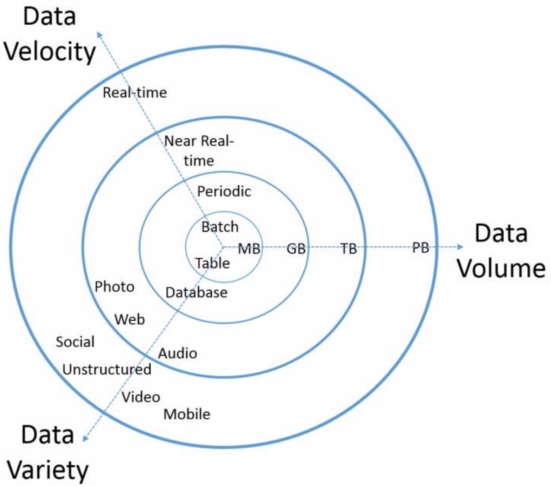
Warm–up quiz
https://wooclap.com
Data-to-big-data

Big Data

Definition

a collection of data sets so *large* and/or *complex* and/or fast changing that they are difficult to process using traditional DBMSs or traditional data processing applications

Big Data – The three V's



Big Data is so . . . *Big*!

The total amount of DATA being captured and stored by industry doubles every 1.2 years

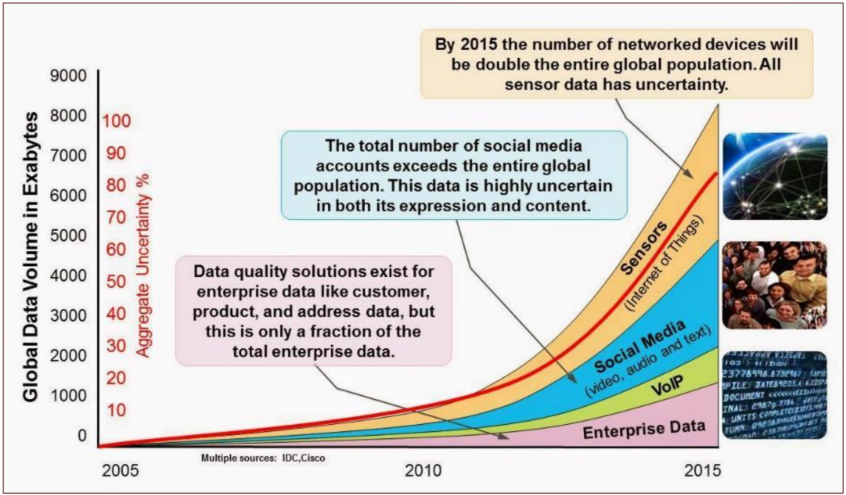
...more data has been created in the past two years than in the entire previous history of the human race

In 2017 over 1 trillion photos will be taken and billions of them will be shared online

In 5 years there over 50 billion smart connected devices in the world

all developed to collect, analyze and share data

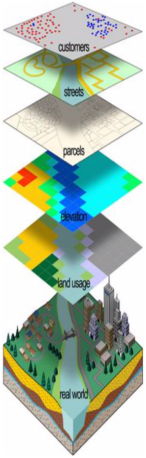
. . . and still *growing*!

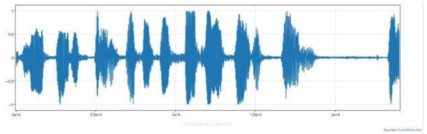


. . . and *complex*!


OBJECT
Sandals
Sunglasses
LOGO
Starbucks
U.S. flag
SCENE
Water
Beach
Sand
OBJECT
Sunglasses
Dog
Face
LOGO
Sierra
Nevada
SCENE
Waterfront
Lake


LOG
127.0.0.1 - -
[01/Dec/2008:00:32:02
-0200] "GET / HTTP/1.0"
200 8235 "-"
"Apache/2.2.3 (Unix)
(internal connection)"


customers
streets
parcels
elevation
land usage
real world




variety... is the spice of life

Big Data – A high level taxonomy

Structured: relational tables, spreadsheet (or data which could easily fit in them)

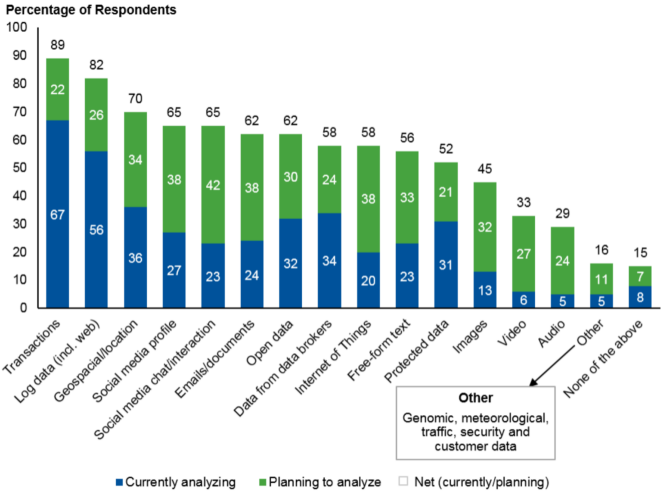
Unstructured: does not have an associated data model

- video, audio, pictures,
- 80% of available data

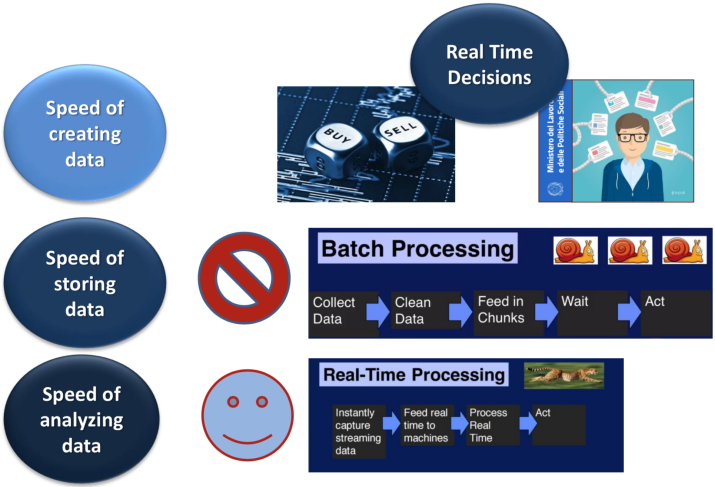
Semi–srtuctured: there is some structure, perhaps data refer to different structures

- self describing data: XML, JSON, ...

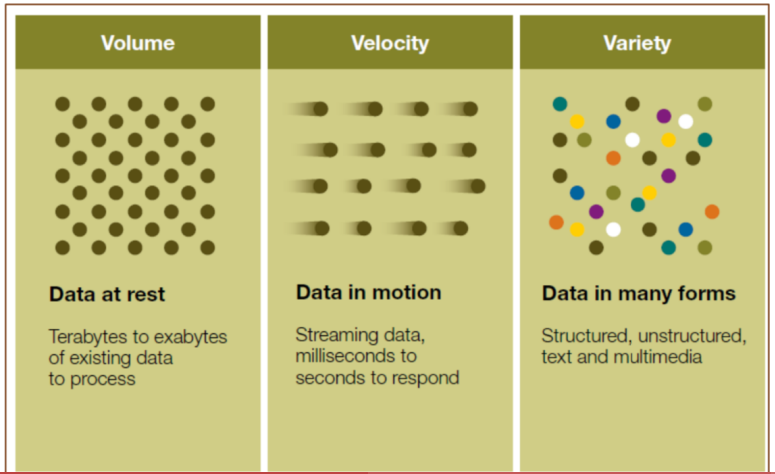
Data Sources to be analysed

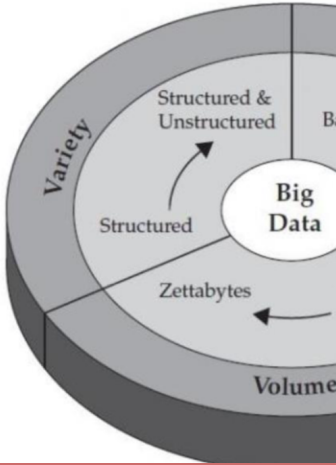


Big Data is so . . . fast!



The V of Big Data (again)





What's the relationship between Big Data and Cloud Computing?

1. Cloud Computing is relevant also if you do not have Big Data
2. Big Data can also be processed without Cloud Computing
3. In many cases Cloud Computing is a key asset to be able to deal with Big Data

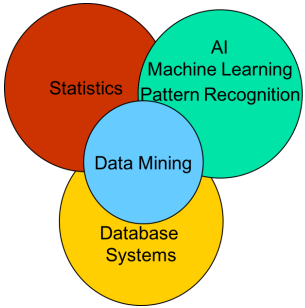
   because in presence of one or more of the V it is difficult to use traditional databases or traditional data processing

Can you imagine uses cases for statements 1 and 2?

1 General information 2
2 Data in organisations 6
3 Data Mining and Big Data 27
4 Cloud Computing 52
5 Big Data 58
6 Data Mining 70

Data Mining Origins

- The sizes of the circles to not reflect the relative importance/size of the topics
- Many textbooks referring either to *machine learning* or *data mining* have a significant overlap, sometimes the separation between the two topics is a little *fuzzy*



Data Mining $\rightleftharpoons$ Machine Learning

In the following we will use the topic names as follows

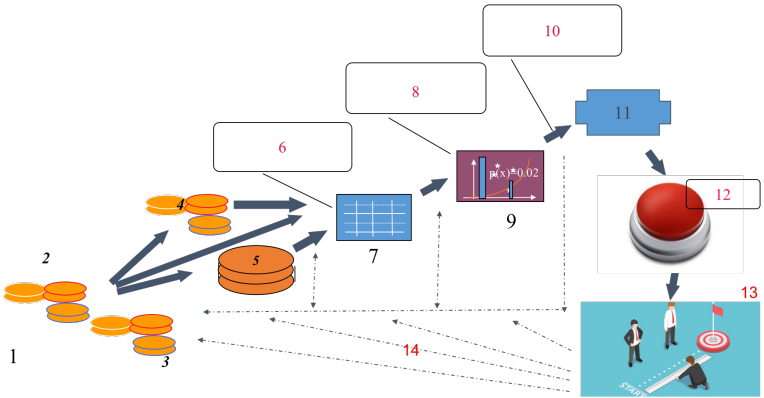
- Data mining is the discovery process described in page 73
- Machine learning for data mining is the core of learning models and algorithms which allow to extract actionable patterns from data

Looking at the literature

- Machine learning includes also other concepts and methods which are not used for data mining
- Data mining books frequently include also *learning models* which are not traditionally covered in machine learning literature
  - Look here for a comprehensive list of data mining topics

The Data Mining Process – attach labels to numbers

Internal data
Selection and pre-processing
Machine Learning
Knowledge
Interpretation and evaluation
Prepared data
Data Lake
Patterns and models
External data
Measure
Data Warehouse
Take action
Data Sources
Change



Watch this

https://www.youtube.com/watch?v=EH3bp5335IU

Caveat: in the clip you have an example of the interchange between the terms Data Mining and Machine Learning